

Integrated Thermal Analysis of the Iodine Satellite (iSAT) from Preliminary to Critical Design Review

Stephanie Mauro

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Outline

- Why iSAT?
- What is iSAT?
- Challenges
- Design
- Heat Loads
- Environments
- Evolution
- PDR/IDR Model
- IDR Results
- CDR Model
- Solutions to Challenges
- Key Takeaways

Why iSAT?

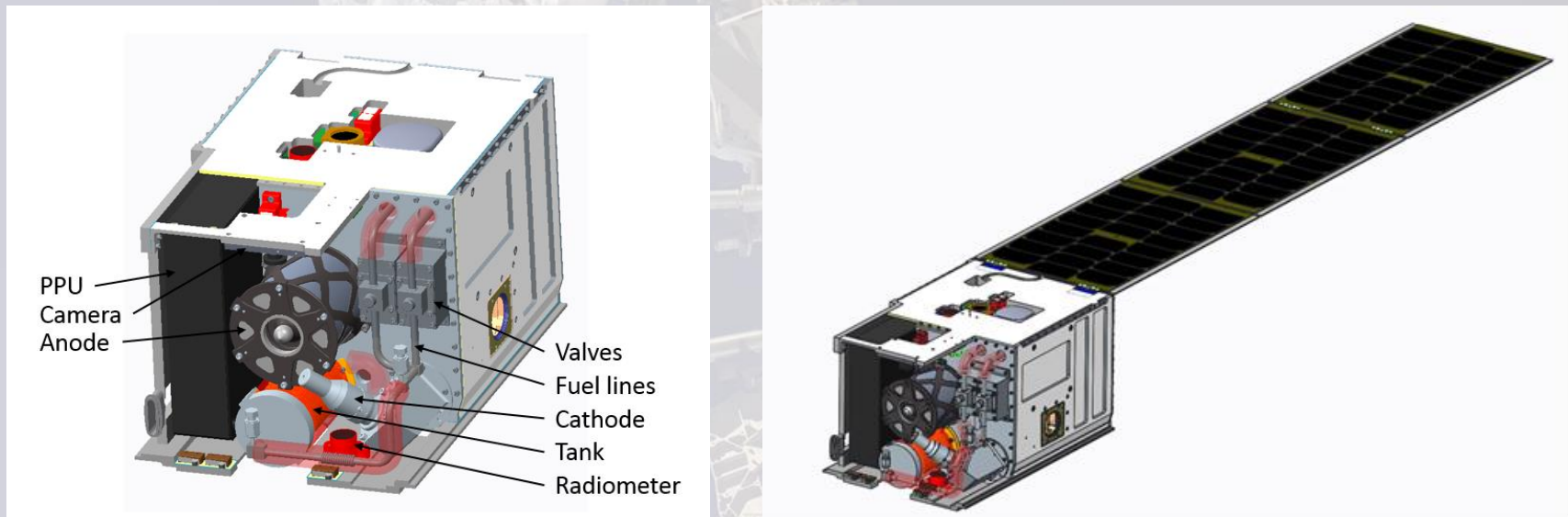
- Further technology of cubesat propulsion
 - Demonstrate Busek Space Propulsion and Systems iodine-fueled Hall Effect Thruster (HET)
 - Iodine provides high thrust-to-mass ratio
 - Iodine can be stored as a solid at low pressures and sublimated to a gas for use as a fuel
 - Characterize effects of iodine fuel on spacecraft



http://www.busek.com/technologies__hall.htm

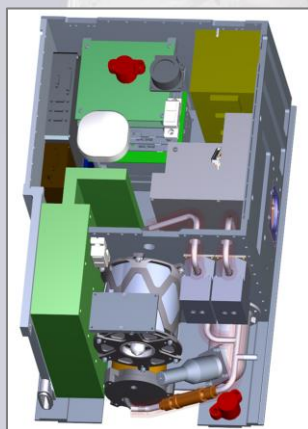
What is iSAT?

- 12U Cubesat with 1 year mission

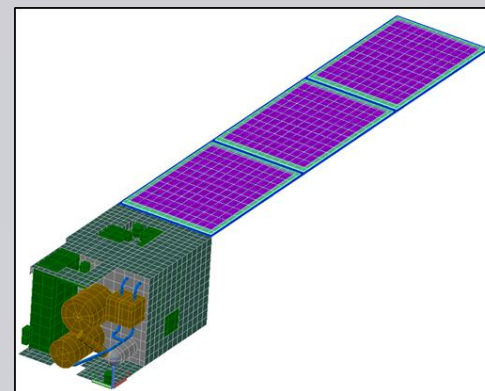


Challenges

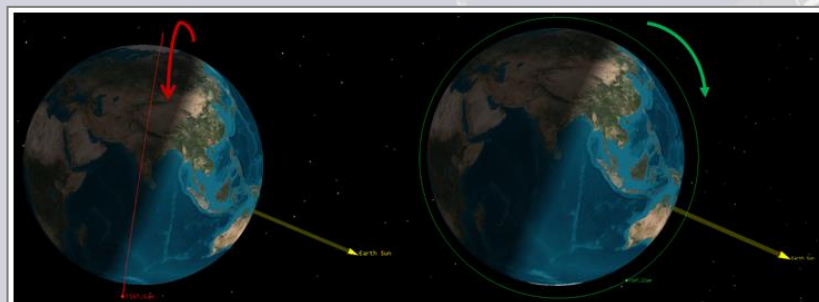
Volume



Power & Thermal



Environments

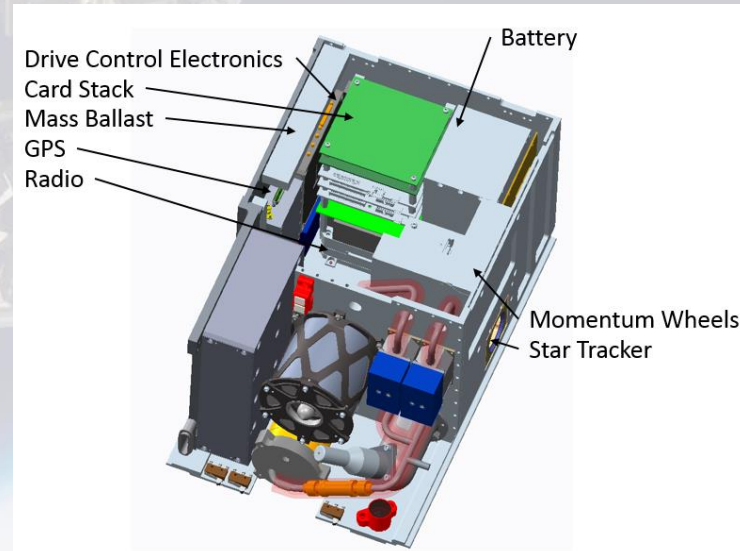
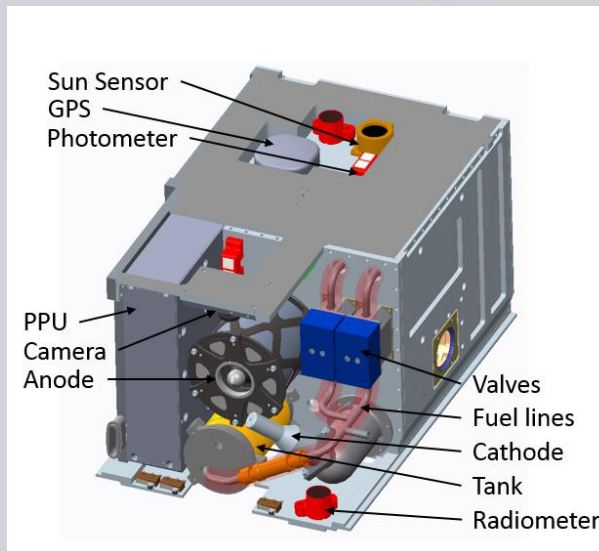


Unknowns



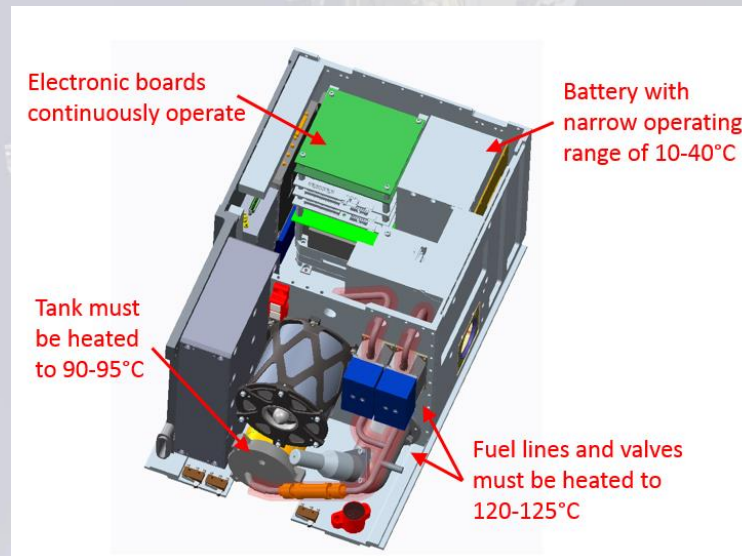
Volume

- Volume constraints are a typical challenge for cubesats
 - The propulsion components use about 1/3 of the total volume of the cubesat.
 - The majority of the propulsion components are exposed to deep space
 - A portion of the PPU and fuel lines are enclosed within the chassis due to volume constraints.
 - Large battery to accommodate power needs
 - Specialized electronics cards in non-COTS packaging



Power & Thermal

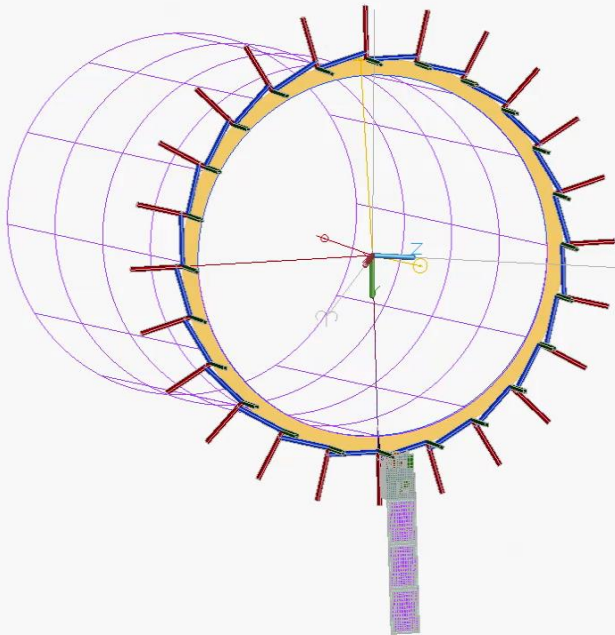
- There are high thermal heat loads caused both by a high power density of the spacecraft, and by temperature requirements of the propulsion components.
 - There are high power requirements for several components.
 - HET requires 200W to fire, with an additional 100W cathode heater
 - Electronics cards are powered on continuously
 - The propulsion system has high temperature requirements during thrust.
 - Fuel lines and valves must be 120 - 125°C
 - Tank must be 95 - 100°C



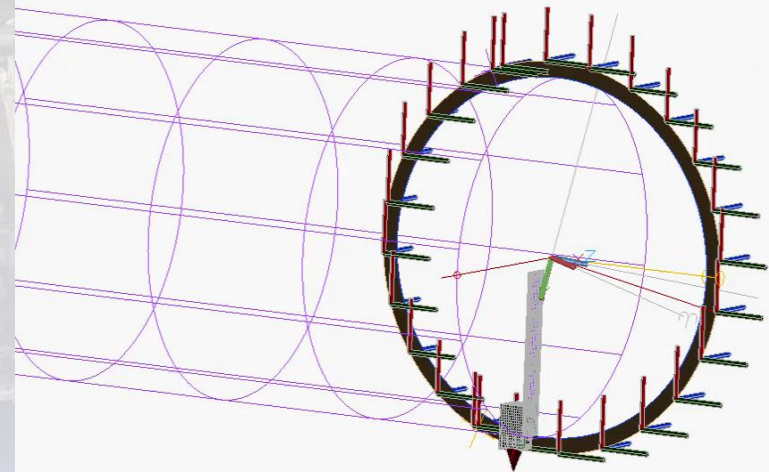
Environments

- iSAT experiences a range of environments for a small satellite.
 - iSAT's orbit will full eclipse and up to 8 days of and full sun.
- Both worst case hot and cold orbits must be simulated to bracket expected temperatures.

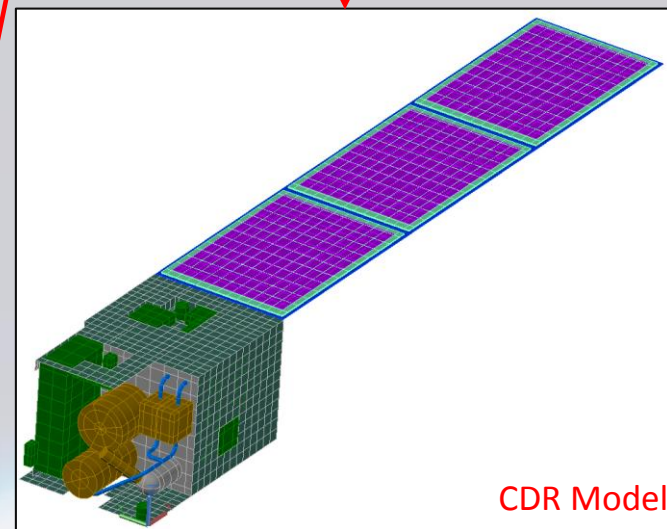
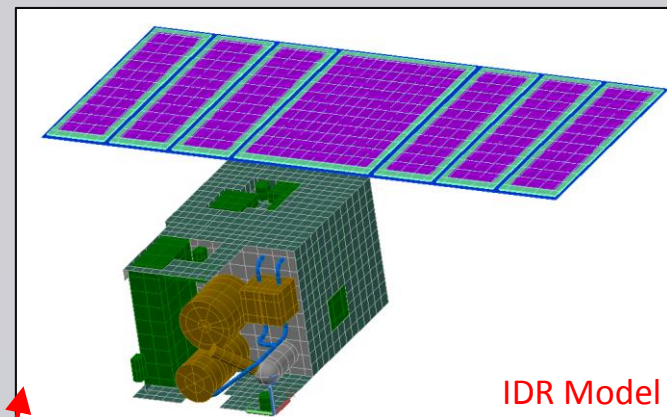
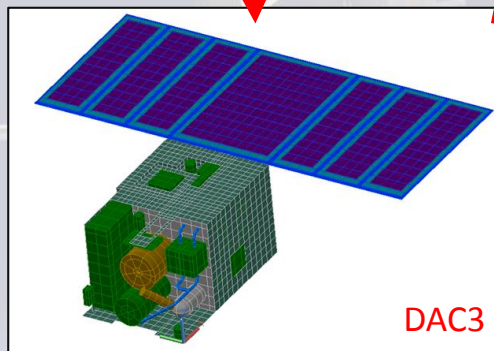
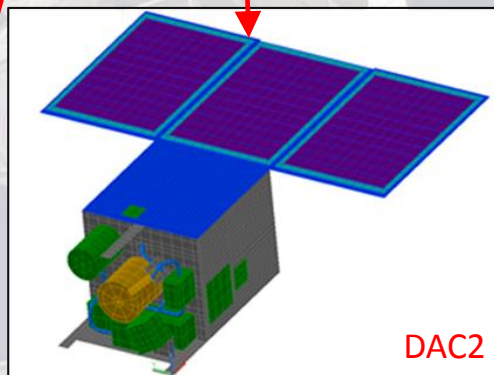
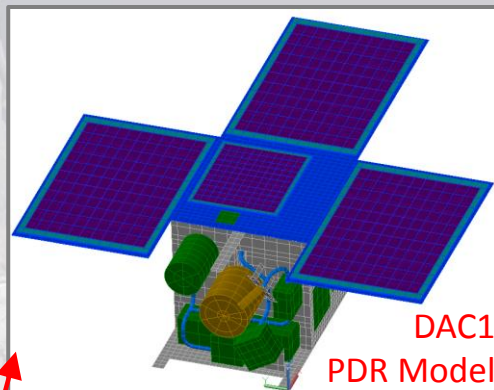
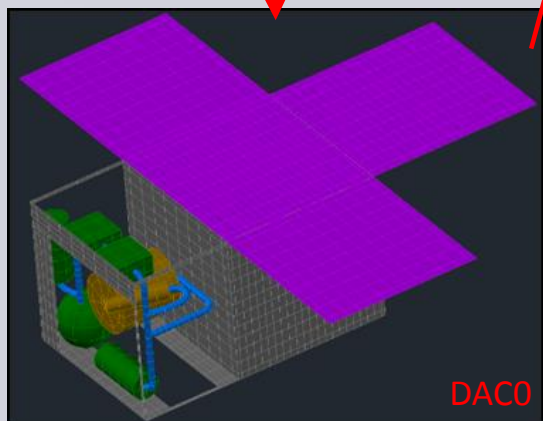
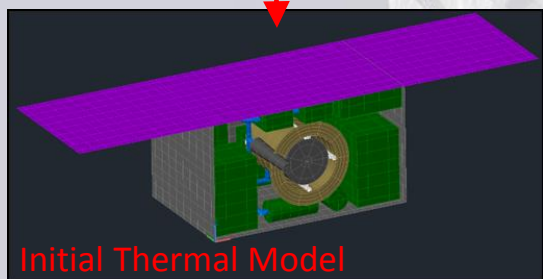
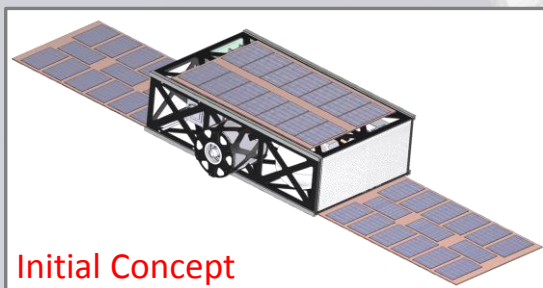
Hot Env. Orbit



Cold Env. Orbit

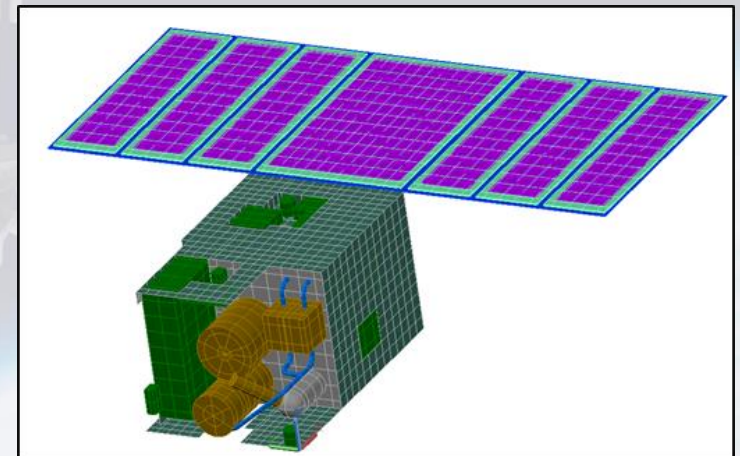
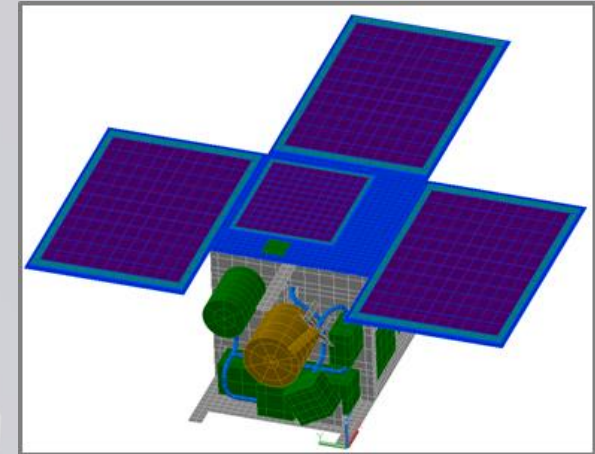


Evolution



PDR/IDR Model

- Driving geometry updates
 - Solar panel configuration
 - Propulsion components configuration
 - Larger cathode mount
 - Larger PPU
 - Fuel line re-routing
- Driving thermal updates
 - 100W Heater added to cathode for propulsion operation
 - Thruster firing frequency decreased
 - Heat dissipations of components updated



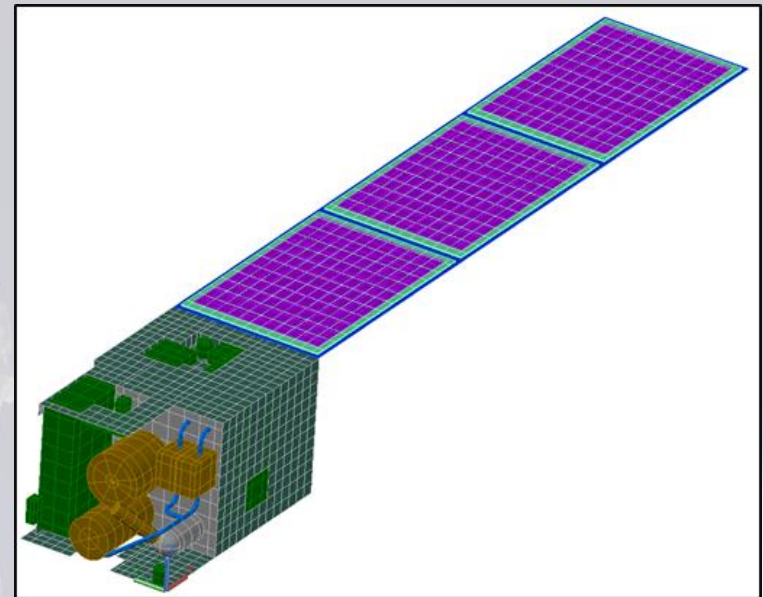
IDR Results

	Above Operational Max
	Within 5 °C of Operational Max
	Within 5 °C of Operational Min
	Below Operational Min

Component Name	Survivability [C]		Operational [C]		Hot Environment Predicted [C]		Cold Environment Predicted [C]	
	Max	Min	Max	Min	Max	Min	Max	Min
Power Management Board	60	-20	60	-20	44	14	33	2
Power Distribution Board	60	-20	60	-20	46	14	36	2
Flight Computer	70	-20	60	-40	54	13	44	2
Auxiliary Board	85		85		42	13	32	1
Input/Output Board	85		85		41	14	31	2
PPU Switch Board					19	13	10	-5
Camera	85	-24	70	-5	16	10	2	-3
Thruster	200		200		106	-6	95	-21
PFCVs	150	12	150	12	127	-12	126	20
PPU	125		125		19	8	10	-5
Cathode	450*		450*		300	13	294	-44
Iodine Fuel	150*		150*		95	29	95	5
Tank	150*		150*		96	-37	95	5
Fuel Lines	150*		150*		187	20	198	5
Fuel Line section to Cathode	150*		150*		240	14	230	0
Battery	50	-20	45	10	19	13	9	1

CDR Model

- Driving geometry updates
 - Solar panel configuration
 - Propulsion system fidelity
 - A high fidelity thermal model was created to be included in CDR
- Driving thermal updates
 - Propulsion system operation timeline
 - Orbit parameters defined
- Thermal changes to address IDR issues
 - Propulsion system definition – isolation where necessary
 - Battery
 - Thermally isolating washers used for mounting
 - 3W heater added
 - Spacecraft coatings may be updated
 - Thruster firing frequency may be dictated
 - Orientation of spacecraft is flexible when not firing



Solutions to Challenges

- Volume
 - Eliminate unnecessary components
- Power
 - Deployable solar panels
 - Reduce frequency of thruster firing
- Thermal
 - Isolation of components
 - Heater use when necessary
 - Adjust spacecraft coatings
 - Reduce frequency of thruster firing
 - Dictate spacecraft orientation
- Environments
 - Bracket possible environments
- Unknowns
 - Parameterize modeling efforts

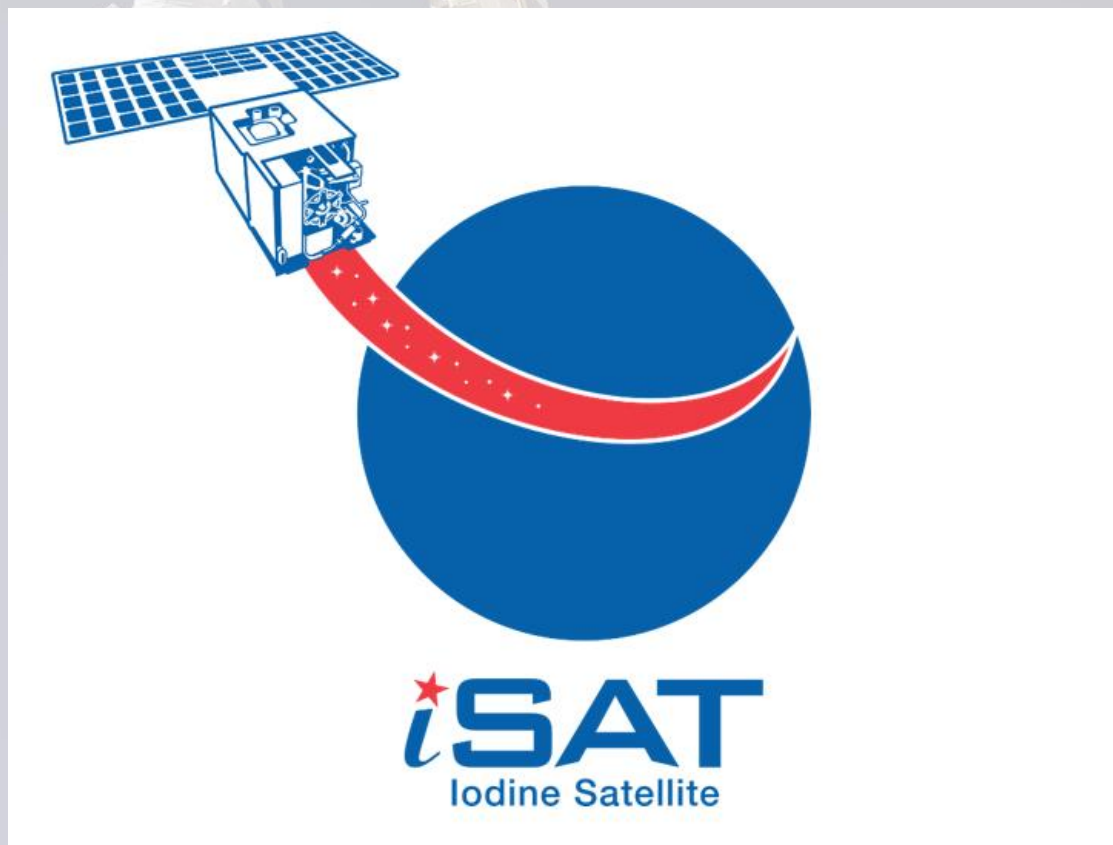
Forward Work

- Critical Design Review in late August
- Integrate completed high fidelity propulsion model
- Incorporate finalized operational timeline into thermal model
- Thermal Vacuum cycle and balance test plans

Key Takeaways

- Challenges of cubesats
 - Volume / size
 - Power
 - Thermal
 - Environments
- Modeling challenges
 - Unknowns / evolving design
 - Thermal Desktop symbols, aliases, and articulators have been useful modeling tools.
 - Bracketed environments may all be experienced during flight.
- Small changes matter more for small spacecraft!

Questions?



Back-up: IDR Results Hot Environment

Subsystem	Component Name	Survivability [C]		Operational [C]		Predicted [C]	
		Max	Min	Max	Min	Max	Min
Power	PMB	60	-20	60	-20	44	14
Power	PDB	60	-20	60	-20	46	14
GNC	Momentum Wheels Assembly	70	-30	60	-20	23	12
GNC	Momentum Wheels DCE	70	-30	60	-20	22	16
GNC	Star Tracker	70	-30	65	-30	22	11
GNC	IMU	85	-40	85	-40	21	9
GNC	GPS	85	-40	85	-40	16	7
GNC	GPS Antenna	85	-55	85	-55	19	11
GNC	Sun Sensor	85	-40	75	-25	21	11
GNC	Magnetometer	125	-55	80	-40	17	9
Comm	Transceiver	110	-55	85	-40	15	11
GNC	S-band Antenna	100	-65	100	-65	18	4
C&DH	FC	70	-20	60	-40	54	13
C&DH	AB	85	-20*	85	-20*	42	13
C&DH	I/O	85	-20*	85	-20*	41	14
Propulsion	PPU Switch Card	85*	-20*	85*	-20*	19	13
Propulsion	Camera	85	-24	70	-5	16	10
Propulsion	Thruster	200		200		106	-6
Propulsion	PFCVs	150	12	150	125	127	-12
Propulsion	PPU	125	-20*	125	-20*	19	8
Propulsion	Cathode	450*		450*		300	13
Propulsion	Iodine Fuel	150*		150*	90	95	29
Propulsion	Tank	150*		150*	90	96	-37
Propulsion	Fuel Lines	150*		150*	120	187	20
Propulsion	Fuel Line section to Cathode	150*		150*	120	240	14
Power	Battery	50	-20	40	10	19	13
Power	Solar Cells	110		100		84	-37
Payload	Radiometer Top	150	-60	120	-50	8	-2
Payload	Radiometer Thruster Plate	150	-60	120	-50	20	8
Payload	Radiometer Bottom	150	-60	120	-50	15	4
Payload	Photometers	150	-60	120	-50	14	4
Structure	Separation Switch					12	10
Structure	Solar Panel FR4	110		100		81	-37
Structure	Solar Panel Al Support	110		100		74	-36
Structure	Cathode Mount	120*		120*		10	260
Structure	Chassis	120*		120*		5	34

Back-up: IDR Results Cold Environment

Subsystem	Component Name	Survivability [C]		Operational [C]		Predicted [C]	
		Max	Min	Max	Min	Max	Min
Power	PMB	60	-20	60	-20	33	2
Power	PDB	60	-20	60	-20	36	2
GNC	Momentum Wheels Assembly	70	-30	60	-20	10	-1
GNC	Momentum Wheels DCE	70	-30	60	-20	12	5
GNC	Star Tracker	70	-30	65	-30	10	-2
GNC	IMU	85	-40	85	-40	12	-4
GNC	GPS	85	-40	85	-40	6	-4
GNC	GPS Antenna	85	-55	85	-55	7	-2
GNC	Sun Sensor	85	-40	75	-25	8	-2
GNC	Magnetometer	125	-55	80	-40	6	-2
Comm	Transceiver	110	-55	85	-40	4	0
GNC	S-band Antenna	100	-65	100	-65	8	-6
C&DH	FC	70	-20	60	-40	44	2
C&DH	AB	85	-20*	85	-20*	32	1
C&DH	I/O	85	-20*	85	-20*	31	2
Propulsion	PPU Switch Card	85*	-20*	85*	-20*	10	-5
Propulsion	Camera	85	-24	70	-5	2	-3
Propulsion	Thruster	200		200		95	-21
Propulsion	PFCVs	150	12	150	125	126	20
Propulsion	PPU	125	-20*	125	-20*	10	-5
Propulsion	Cathode	450*		450*		294	-44
Propulsion	Iodine Fuel	150*		150*	90	95	5
Propulsion	Tank	150*		150*	90	95	5
Propulsion	Fuel Lines	150*		150*	120	198	5
Propulsion	Fuel Line section to Cathode	150*		150*	120	230	0
Power	Battery	50	-20	40	10	9	1
Power	Solar Cells	110		100		80	-61
Payload	Radiometer Top	150	-60	120	-50	3	-8
Payload	Radiometer Thruster Plate	150	-60	120	-50	10	-5
Payload	Radiometer Bottom	150	-60	120	-50	-3	-10
Payload	Photometers	150	-60	120	-50	2	-8
Structure	Separation Switch					1	-2
Structure	Solar Panel FR4	110		100		77	-61
Structure	Solar Panel Al Support	110		100		72	-61
Structure	Cathode Mount	120*		120*		249	-5
Structure	Chassis	120*		120*		26	-6